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# The Impact of Fertilizer on Soviet Grain Output, 1960-80

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*Central Intelligence Agency*
*National Foreign Assessment Center*

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## *Key Judgments*

Since 1960, grain output in the USSR has increased about 6 million tons a year on the average. About one-fifth of this gain is attributable to an elevenfold increase in fertilizer use. Before 1965, grain was a low priority recipient of fertilizer. Between 1965 and 1975, however, applications rose from 6 million to 25 million metric tons. The impact of fertilizer would have been even greater except for major problems with application technology, storage, and quality, which have held fertilizer gains well below their potential. These problems are gradually diminishing but will still be important.

The USSR plans to double fertilizer applications during the current five-year plan (1976-80) as the chief way of achieving a one-fifth increase in annual average grain output over 1971-75. Planned grain output during 1976-80 will average 220.4 million tons per year. Over the range of expected rates of application during 1976-80, we estimate that each additional ton of fertilizer will add approximately 1.1 tons of grain output.

While the greater use of fertilizer clearly will aid Brezhnev's efforts to bring grain production up to the high levels needed to support his livestock program, it will not be sufficient to ensure achievement of the grain target. Substantially better than normal weather, as occurred in 1976 and 1977, as well as better nonfertilizer technology are also needed.

Two projections of average annual grain production have been made based on different assumptions of fertilizer use.

- Projection I assumes that Soviet plans for fertilizer applications and other technological advances are achieved. This increment, when applied to a 1975 base projected from Soviet grain output in 1962-65—

a period of nearly normal weather—suggests an average crop of about 212 million tons during 1976-80.

- Projection II is based on attainment of (a) 80 percent of the fertilizer goals and (b) 50 percent of the planned gains from other technological improvements. Projection II is consistent with the experience of recent years. Using the weather-adjusted 1975 base results in an average crop of 200 million tons for 1976-80.

Beyond 1980, we expect continued large increases in applications of fertilizer to grain. Planning authorities have incentives to increase applications. Even after the state subsidies are included in the price paid by state and collective farms, the ratio between the current value of fertilizer's contribution to grain output and its cost is more than 3 to 1. This ratio will remain well above 2 to 1 even if fertilizer applications grow during 1981-85 at the rapid rates planned for 1976-80.

Projection II, based on assumptions that seem more probable than those of Projection I, is about 10 percent below 1976-80 Soviet grain goals for average annual grain output and 25 million to 30 million tons less than our estimates of average annual grain requirements for 1976-80. Annual average purchases of foreign grain could thus be as large as those following the 1972 and 1975 grain harvest failures if the Soviets choose to cover the deficit by imports. It is more likely, however, that a grain crop failure would be followed by a reduction of short-run goals for meat output and livestock inventories.

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FIGURE 1

# The Impact of Fertilizer on Soviet Grain Output, 1960-80

## Introduction

Since 1960 both average grain yields and total grain output in the Soviet Union have increased roughly 55 and 78 percent, respectively. Much of this improvement is weather-related, but part results from increased fertilizer use and other improvements in technology. During this period, the amount of fertilizer allocated to grain crops increased elevenfold. Only since the late 1960s has fertilizer use on grain become relatively widespread. Nevertheless in 1975, less than half the grain crop was fertilized.

Soviet planners are calling for annual average grain output to reach 220.4 million tons during 1976-80—about 20 percent more than annual average output for 1971-75. The importance to the economy of rapidly increasing grain output is difficult to overstate.

- Brezhnev's livestock program is limited in part by the availability of grain.
- More meat on Soviet tables is a basic plank in the regime's program to raise levels of living.
- Massive grain imports in drought years contribute to large hard currency deficits and limit Soviet ability to purchase much needed Western technology.

Success in boosting grain output during 1976-80 will depend on weather and fulfillment of ambitious plans for technological improvements in grain growing, especially increased use of fertilizer. An earlier study on the relationship between weather and grain output concluded that weather during 1976-80 is likely to be worse than that in the recent past, which was unusually favorable.[1]

This report—using the weather-related trends established in the earlier report on Soviet climate conditions—assesses the probable impact of increased use of fertilizer and other technological advances on grain output during 1976-80. It (a) briefly describes the conditions under which grain grows in the Soviet Union and the benefits derived from fertilizer use, (b) traces recent trends in fertilizer applications to grain and discusses the impact that fertilizer has had on grain yields, and (c) examines Soviet grain prospects during the Tenth Five-Year Plan, presenting two projections of grain production for 1976-80 based on fertilizer application plans and likely response rates.

## Environmental Constraint on Fertilizer Use

Only a small proportion of the Soviet Union's vast land area is suitable for grain growing.[2] The grain belt extends nearly 4,800 kilometers from the western border of the USSR to the Mongolian border in the east (see figure 1). In 1975, 128 million hectares were planted in grain, almost 60 percent of the total sown area in the USSR. Spring wheat (42 million hectares) and spring barley (31 million hectares) accounted for three-fifths of the area sown to grain. Winter grains—winter wheat, barley, and rye—covered 29 million hectares, or about one-fifth of the total grain area.

[1] CIA, *USSR: The Impact of Recent Climate Change on Grain Production*, ER 76-10577U, October 1976.

[2] The tillable area exceeds that of the United States, but overall productive capabilities per hectare are considerably lower.

Vast differences in soil and climate in the grain belt affect the production of grain and the impact of fertilizer on grain yields. In general, available moisture determines the areas where fertilizer can be used most effectively. As fertilizer applications increase, the moisture required to secure full benefits also increases. Although half of Soviet arable land nominally has adequate moisture for grain growing, precipitation varies widely from year to year and from region to region. Furthermore, untimely seasonal distribution often reduces its effectiveness.

Most grains require at least 10 inches of precipitation per year and a frost-free growing season of at least 90 days. These conditions generally are met or exceeded as far south as the chernozem (black earth) soil belt. The chernozem zone—where wheat, barley, and corn sowings are concentrated—extends from western Siberia through northern Khazakhstan and a large portion of the southern European USSR. The relatively high water-holding capacity of chernozems enhances their ability to accommodate fertilizer, particularly in regions with low precipitation.

North of the chernozem zone, annual precipitation ranges from 20 to 25 inches. While the response of grain to fertilizer is higher than in the chernozem zone, soils are heavy and acidic, requiring large applications of lime and fertilizer for best results. Soviet planners have designated much of the northwestern USSR as the "zone of guaranteed moisture." This area, which consists mainly of the Baltic republics, Belorussia, and the nonchernozem region of the Russian Soviet Federated Socialist Republic (RSFSR), is considered a prime area for increasing and stabilizing crop yields through land reclamation and greater use of fertilizer.

West of the Urals and in the Volga Valley, annual precipitation usually is adequate to meet grain growing needs. Rainfall varies from year to year, usually peaking in July or August—too late to benefit much of the crop. Precipitation decreases eastward and is lowest in the desert steppes. In these areas, rainfall is light, variable, and unpredictable. Grain yields are low, and mineral fertilizer is applied sparingly except where grain lands are irrigated. Application of fertilizer in drought conditions usually is counterproductive.

When applied properly, mineral fertilizers supplement the soil's nitrogen, phosphorus, and potassium used during plant growth. In most areas, Soviet grains benefit from annual applications of nitrogen, which is needed to form plant proteins that are contained in leaves and seeds. Grain crops also benefit from (a) cumulative effects of fertilizer applied in earlier years and (b) predecessor crops.

More than half of Soviet arable land, especially areas with podzolic or chestnut soil, is deficient in phosphorus, which is needed for rapid seed formation, plant maturation, and resistance to cold temperatures—desirable characteristics in the short Soviet growing season. Soviet soils contain large quantities of potassium, which promotes kernel development and the formation of carbohydrates. Natural potassium in the form of insoluble silicates, however, is not easily available to plants throughout much of the Soviet grain belt; therefore, readily soluble potassic fertilizers are needed.

### Allocation of Fertilizer

In the USSR, central planning replaces the market; facing chronic fertilizer shortages, planners make allocations mainly according to (a) crop priorities and (b) where "fertilizers will yield the greatest effect for the national economy"—that is, where the marginal product of fertilizer is highest.[3] Analysis of the distribution of fertilizer among Soviet grain growing areas suggests that the planners attempt to equalize the marginal product of fertilizer by region.

Currently, prices for fertilizer and grain are structured to encourage fertilizer use, especially where response rates are high. The prices Soviet farms pay for fertilizer are set below production

[3] N. N. Baranov, *Ekonomika ispol'zovaniya udobreniy*, Moscow, 1974, p.17.

costs by the government; grain and other crop prices are set sufficiently high that, on average, fertilizer use is highly profitable. For example, one Soviet author claimed that in 1972, a relatively poor crop year, collective and state farms paid 1.5 billion rubles for fertilizer and produced 6.3 billion rubles of additional crops. Even with the government subsidy [4] added, the ratio of the revenues from sale of the additional output to the cost of fertilizers was more than 3 to 1.[5]

The planning process begins with setting targets for grain yields by administrative region and estimating the portion of the yield increase that is to come from fertilizer. The amount of fertilizer needed to meet grain output targets is derived from regional fertilizer application norms that indicate the fertilizer nutrients necessary to increase grain output by one ton. These norms, derived from experimental plots in various soil-climate zones, show yield responses to weather and other growing conditions. Only if these growing conditions do not change over the plan period will these norms be valid. At current levels of application, the grain crops that are most responsive to fertilizer—irrigated rice and corn—are given priority in applications. Priority declines with response rates that run from those of winter grains to those of spring wheat, barley, oats, legumes, millet, and buckwheat.

Allocation is designed to provide farms with the fertilizer they need to meet plan targets for crop yields. In practice, however, production and delivery bottlenecks mean that actual fertilizer allocations are rarely sufficient to meet the plan for grain even if precipitation is normal or above normal. At present, much of the spring grain area gets only the aftereffects of fertilizer applied to predecessor crops. Some shortages are made up by diverting fertilizer from sown grasses and pasturage to grain crops.

[4] We estimate fertilizer subsidies averaged 400 million rubles per year during 1971-75.

[5] The financial incentive to fertilize wheat crops is relatively greater in the USSR than in the US. The ratio of wheat prices to fertilizer prices in 1976 was 0.68 for the USSR and 0.41 for the US.

Soviet farmers face other problems with fertilizer not normally encountered by their Western counterparts. These include:

- *Low quality:* In 1975 the average nutrient content of fertilizer was only 35 percent, compared with approximately 43 percent in the US. The low nutrient content in the USSR means higher transportation and application costs to the farms per unit of nutrients. Granular fertilizers, which are much easier to apply than powders, account for only 40 percent of fertilizer supplies, far short of the 85 to 90 percent recommended by Soviet experts.[6] Much of the nitrogen content in ammonia water is lost through evaporation. Furthermore, phosphate meal comprises a large share of phosphorus fertilizer despite its insolubility in water. Also, the production of multinutrient fertilizers—those with optimal ratios of nitrogen, phosphorus, and potassium for specific crops and climatic zones—comprise only 15 percent of Soviet fertilizers, whereas in the US it is more than 50 percent.[7] Finally, the Soviets produce only six types of multinutrient fertilizers; Soviet experts consider a minimum of 12 to 13 types necessary.[8]
- *Improper mix:* Fertilizer application norms indicate that on average Soviet grain crops need nitrogen and phosphorus nutrients in a ratio of 1 to 1.2.[9] In 1975, however, the average proportion was one part nitrogen to 0.61 parts phosphorus. This shortfall may result partly from the steady decline of

[6] Despite higher wholesale prices, concentrated granulated, multinutrient fertilizers are less expensive to use per ton of nutrient than single nutrient, powdered fertilizers. Soviet calculations show that the average cost in 1971 for acquiring and applying one ton of single nutrient fertilizer was 222 rubles for nitrogen, 212 rubles for phosphorus, and 75 rubles for potassium. The comparable cost for multinutrient fertilizers, however, was only 174 rubles per ton (Baranov, *op. cit.*, pp. 316-317).

[7] *Vestnik sel'skokhozyaystvennoy nauki,* No. 4, 1976, p. 48.

[8] *Khimiya v sel'skom khozyaystve,* No. 10, 1976, pp. 3-9.

[9] These averages mask considerable diversity in requirements by area and crop. For example, the norm for nitrogen on spring wheat in the Urals is about 80 kilograms of nutrients, while the nitrogen-phosphorus ratio is about 1 to 1.5. In the central region, spring wheat requires 100 kilograms of nitrogen and a nitrogen-phosphorus ratio of 1 to 1.05.

phosphorus nutrients as a share of fertilizer deliveries to agriculture. Past fertilizer production and allocation policy has emphasized nitrogen fertilizers.

- *Excessive losses:* By Soviet accounts, 10 to 15 percent of the fertilizer earmarked for agriculture is lost during transportation and storage because of uncovered trucks, spillage in handling, and storage in open areas where moisture causes caking and loss of nutrients. This can be compared with a 5-percent loss rate between factory and field in the US.[10] Construction of proper transport and storage facilities has not kept pace with increases in fertilizer output. For example, in 1975, total fertilizer storage capacity on farms equaled less than 5 million tons, only two-fifths of what Soviet authorities considered adequate.[11]

- *Improper application:* Inefficiency on Soviet farms is keeping crop yields below what they should be with current levels of fertilizer application. Widely used application techniques, such as broadcasting and aerial application, are very inefficient and cause excessive losses. Farm managers chronically complain of insufficient technical information on optimal fertilizer application rates, late deliveries of fertilizer, and shortages of machinery to mix and to apply fertilizer. Currently, farms have 30 to 40 percent of needed fertilizer application machinery.[12] As a result, applications are often too late to benefit crops. Furthermore, underfulfillment of requirements for lime and organic fertilizer supplements dampen the benefits obtained from mineral fertilizers.[13] The relative price of liming materials and grain supports the implied contention that the marginal product of liming greatly exceeds the marginal cost. A Soviet calculation indicates that inadequate applications of lime currently reduce grain production by about 12 million tons.[14]

## Impact of Fertilizer on Grain Yields

The use of fertilizer on grain in the USSR has become widespread only recently (see table 1).

[10] US Department of Agriculture, unpublished estimate.

[11] *Ekonomicheskaya gazeta*, No. 52, 1975, p. 9.

[12] *Ibid.*

[13] Organic fertilizers (manure and compost) improve water retention and air circulation in soils and reduce the harmful effects of soil acidity on plant growth; thus, application of organic fertilizer tends to enhance the effects of mineral fertilizer. Between 1965 and 1973, the use of organic fertilizer on grain crops increased from 76 million tons to 185 million tons.

[14] *Zernovoye khozyaystvo*, No. 3, 1976, p. 19.

Table 1

Mineral Fertilizer Applications [1]

Standard Units

| | 1960 | | 1965 | | 1970 | | 1975 | | 1980 Plan | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CPH [2] | MMT [3] | CPH [2] | MMT [3] | CPH [2] | MMT [3] | CPH [2] | MMT [3] | CPH [2] | MMT [3] |
| Grain | 0.2 | 2.2 | 0.5 | 6.0 | 1.2 | 14.6 | 2.0 | 25.2 | 4.0 | 51 |
| Forage crops, grasses, cultivated meadows, and pastures | * | 1.4 | * | 2.6 | 1.2 | 7.2 | 2.0 | 20.9 | 3.1 | 35 |
| Technical crops | | | | | | | | | | |
| Cotton | 11.3 | 2.5 | 13.1 | 3.2 | 16.9 | 4.6 | 18.8 | 5.5 | * | * |
| Sugar beets, industrial | 6.2 | 1.9 | 8.3 | 3.2 | 10.6 | 3.6 | 16.9 | 6.2 | * | * |
| Flax | 5.5 | 0.9 | 5.5 | 0.8 | 5.6 | 0.7 | 4.4 | 3.6 | * | * |
| Sunflower seeds and other | 1.1 | 0.7 | * | * | 1.8 | 1.3 | | | | |
| Potatoes | 2.3 | 1.1 | 3.2 | 1.3 | 6.6 | 2.3 | 10.4 | 8.2 | 10.0 | 10 |
| Vegetables and melons | 2.4 | 0.4 | 4.4 | 0.6 | 5.4 | 0.8 | 8.2 | 1.4 | | |
| Orchards and vineyards | 1.0 | 0.3 | * | * | 2.7 | 0.8 | 7.2 | 2.2 | 7.2 | 2 |

* Not available.

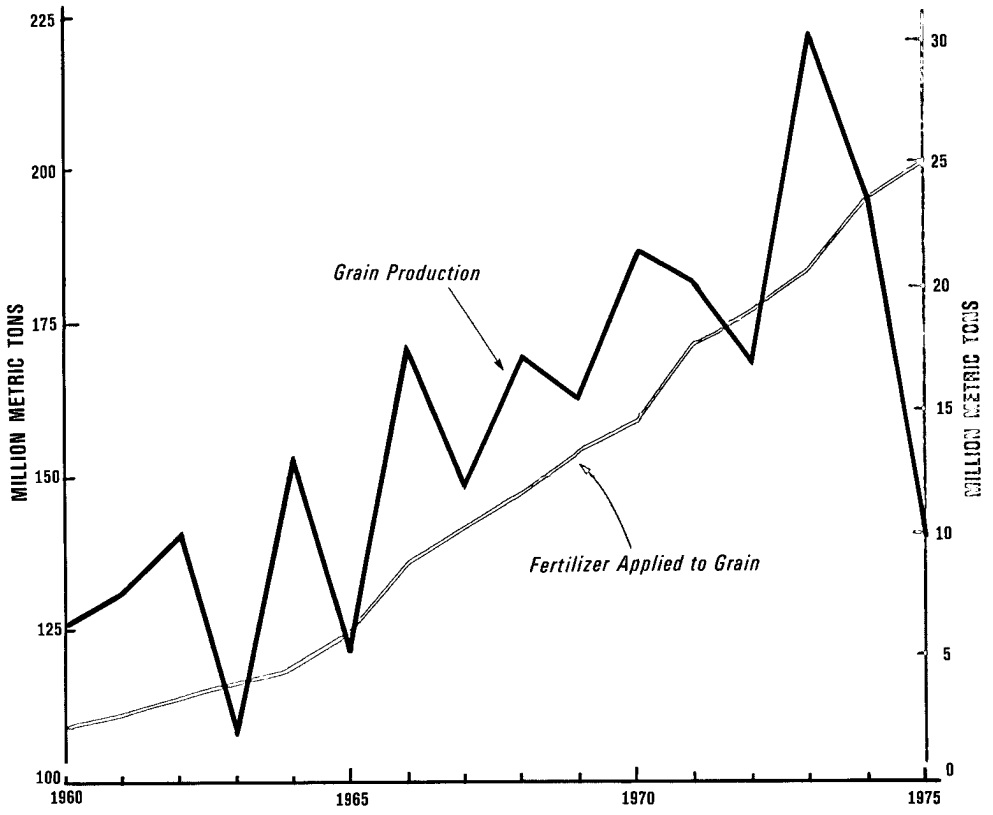
[1] Appendix B contains a description of the methodology and sources used in deriving these estimates.

[2] Centners per hectare.

[3] Million metric tons.

FIGURE 2

## USSR: Grain Production and Fertilizer Applied to Grain

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Until the mid-1960s, Soviet fertilizer policy favored cotton, sugar beets, and potatoes. Since then the priority of grain has risen sharply; in 1975 grain received 7 million tons of fertilizer nutrients,[15] or over one-third of all fertilizer delivered to farms, and 11 times the amount applied in 1960. Still, in 1975 about half the grain area was fertilized.

The response of grain to fertilizer is governed by the law of diminishing returns. The response rate, or the average product of fertilizer, is largest for the initial fertilizer applications. With additional fertilizer use, the response rate drops. When the marginal product of fertilizer reaches zero, additional fertilizer yields no more grain.

Even with good statistical data, the impact of fertilizer on grain is difficult to isolate and to measure. Response rates depend on a host of natural factors, such as weather and soil types; the level and timing of fertilizer use; the responses of different grain varieties; institutional characteristics, such as cropping practices; and the quality of fertilizer. Weather dominates year-to-year changes in grain production, which plummets in drought-stricken years—despite increased use of fertilizer—and soars in years of good weather. For example, Soviet fertilizer applications increased by nearly one-fifth between 1973 and 1975 while grain production declined by two-fifths following years of poor weather (see figure 2).

Because of these factors, response rates of grain to fertilizer are not uniform within the Soviet grain belt (see table 2). The highest and most consistent response rates occur in the nonchernozem soil zone of the RSFSR, Belorussia, the Baltic republics, and the western Ukraine where moisture is adequate for efficient fertilizer use. As expected, these areas receive the most fertilizer.

[15] Nutrient content refers to the sum of nitrogen, phosphorus, and potassium actually applied and excludes ballast or "filler" material. Soviet fertilizer statistics are often expressed in "standard units," which include the filler. Much of what the Soviets call filler, however, is composed of chemically combined elements necessary for the fertilizer compound. Under standard units, nitrogen fertilizers contain 20.5-percent N; phosphate fertilizer, 18.7-percent $P_2O_5$; and potassium fertilizers, 41.6-percent $K_2O$. Unless otherwise stated, fertilizer is expressed in standard units.

Table 2

Fertilizer Response Rates [1]

| | Winter wheat | Winter rye | Spring wheat |
|---|---|---|---|
| Central chernozem | 1.7 | 1.7 | 1.3 |
| Northern Caucasus | 1.4 | 1.3 | 1.0 |
| Wet areas | 1.6 | 1.3 | 1.2 |
| Dry areas | 1.4 | 1.2 | 1.0 |
| Ukraine | | | |
| Western regions | 1.3 | NA | NA |
| Forest steppes | 1.1 | NA | NA |
| Steppes | 1.3 | NA | NA |
| Belorussia | 1.2-1.7 | 1.2-1.5 | NA |
| Estonia | 1.2-1.7 | 1.2-1.5 | NA |
| Latvia | 1.2-1.7 | 1.2-1.5 | NA |
| Lithuania | 1.2-1.7 | 1.2-1.5 | NA |

[1] Tons of grain per ton of standard unit fertilizer. The response rates shown are probably averages for each area in the early 1970s as opposed to the marginal response, i.e., the increment in grain output from the last unit of fertilizer. These response rates could be consistent with marginal responses for all regions.

Sources: N. N. Baranov, *Ekonomika ispol'zovaniya udobreniy*, Moscow, 1974. D. A. Koren'kov, *Vestnik sel'skokhozyaystvennoy nauki*, No. 3, 1971, pp. 46-54.

For example, virtually all grain fields in the Baltic republics receive mineral fertilizer compared with only 20 percent of the grain area in Kazakhstan.

Response rates are lower and less consistent in the steppes of the southern Ukraine, the northern Caucasus, and the southeastern RSFSR. In the drier areas of the northern Caucasus and the Volga Valley, a ton of fertilizer already returns less than a ton of grain. As table 3 and figure 3 show, these drier areas receive lower applications of fertilizer. Furthermore, spring grains dominate in the dry area east of the Urals and generally receive less fertilizer than the fall sown grains that are grown primarily in the moister areas of the European USSR. As a result, spring grain yields are considerably lower than yields of winter wheat.

The lack of Soviet statistical data on fertilizer applications makes it impossible to calculate the exact shape of the average product curve. Trends in the response rate, however, can be roughly gauged from statements by Soviet agronomists. These data suggest a downward trend in average

FIGURE 3

## USSR: Application Rates of Mineral Fertilizer on Grain—1975

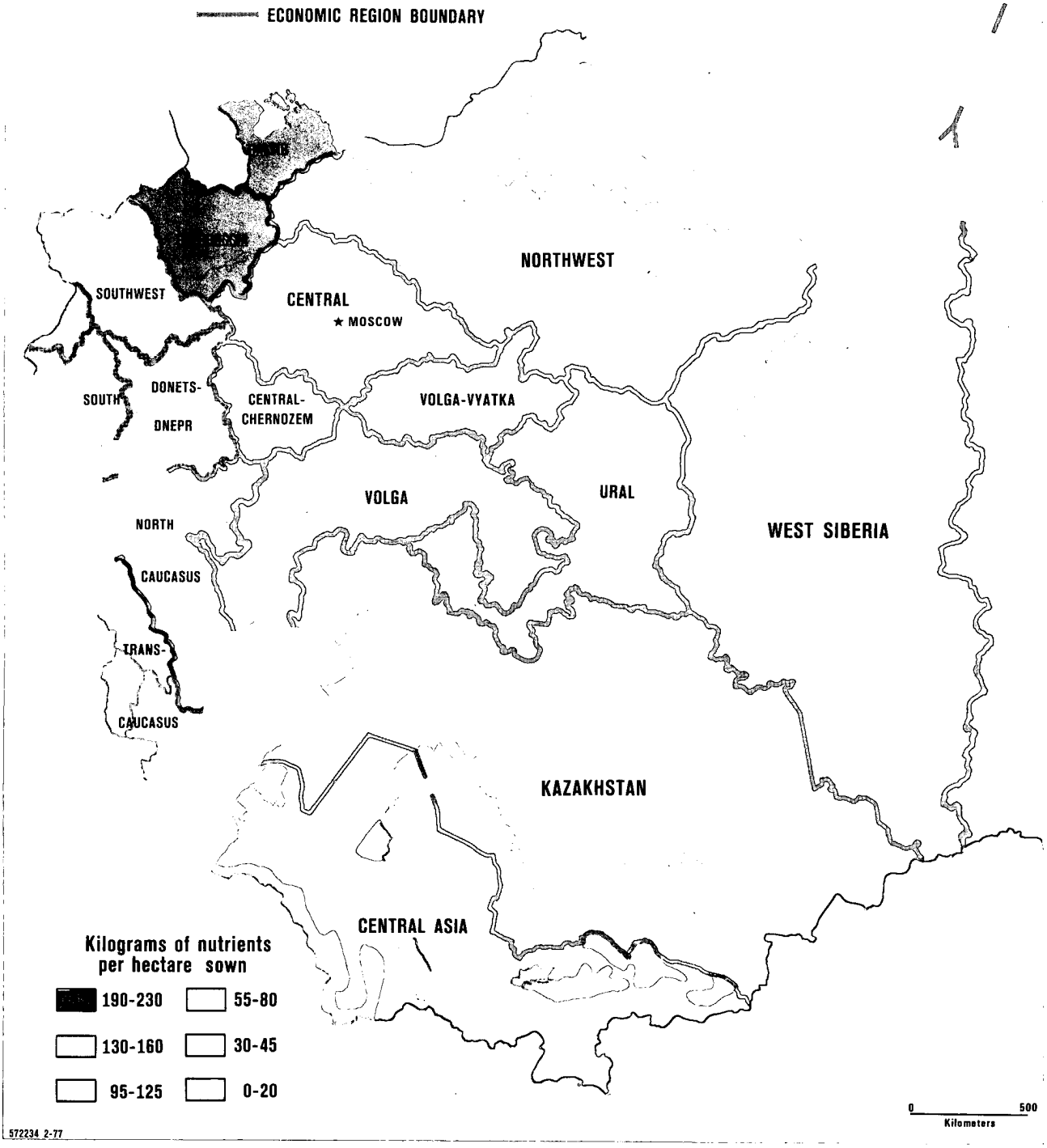

Table 3

Mineral Fertilizer Applications to Grain, 1975

| | Grain area fertilized (Percent) | | Fertilizer application rate [1] | |
|---|---|---|---|---|
| | Corn | Other grains | Corn | Other grains |
| USSR | 93 | 48 | 155 | 42 |
| Belorussia [2] | | 98 | | 230 |
| Latvia [2] | | 98 | | 203 |
| Estonia [2] | | 97 | | 199 |
| Georgia | 94 | 86 | 188 | 136 |
| Lithuania [2] | | 99 | | 140 |
| Kirgiz | 98 | 91 | 278 | 103 |
| Armenia | 53 | 86 | 248 | 120 |
| Turkmen | 88 | 85 | 166 | 95 |
| Moldavia | 86 | 85 | 76 | 109 |
| Ukraine | 98 | 86 | 170 | 70 |
| Azerbaydzhan | 96 | 83 | 222 | 100 |
| Tadzhik | 96 | 66 | 491 | 57 |
| Uzbek | 93 | 35 | 332 | 31 |
| RSFSR | 90 | 47 | 115 | 37 |
| Kazakhstan | 95 | 16 | 302 | 7 |

[1] Kilograms of nutrients per hectare.
[2] Corn is not cultivated in these republics.
Source: *Vestnik statistiki*, No. 5, 1976, p. 95-96.

response rates since 1964—consistent with the law of diminishing returns.

- In 1964 a leading Soviet authority on fertilizer use, N. N. Baranov, claimed that 10 million tons of fertilizer would yield 20 million to 30 million tons of grain—a response rate of 2 to 3. He presumably is referring to the average product of the first 10 million tons of fertilizer. By 1970, according to Baranov, 30 million to 35 million tons of fertilizer would provide at least 45 million tons of grain, implying a lower response rate of 1.3 to 1.5. [16]
- In 1968, Baranov stated that each ton of mineral fertilizer yields 1.2 to 1.5 tons of grain.[17]
- In 1969, two Soviet econometricians constructed a model for optimum fertilizer use on grain. Their data on regional applications and response rates imply a countrywide average response rate of 1.3.[18]
- Baranov alleged that the response of grain to fertilizer was 1.3 in 1970.[19]
- The most recent reference to average response rates states that in 1973 a ton of mineral fertilizer yielded 1.2 tons of grain.[20]

Table 4 summarizes the available information on past response rates. Although the estimates are crude, the pattern of diminishing returns shows clearly.

By fitting the historical application data to the pattern of yield responses above, we estimate that fertilizer accounted for roughly one-fifth to one-quarter of the increase in grain yields since 1960. During 1962-74, overall grain yields rose at an

[16] N. N. Baranov, *Ekonomika ispol'zovaniya udobreniy i gerbitsidov*, Moscow, 1964, p. 145.

[17] N. N. Baranov, *Doklady i soobshcheniya*, No. 45 (sbornik nauchnoissledovatel'skikh rabot), Moscow, 1968, pp. 83-89.

[18] A. V. Sokolov et. al., "Postanovka zadachy khimizatsii zernovogo khozyaystva SSSR," *Ekonomika i matematicheskiye metody*, No. 5, 1969, p. 717.

[19] N. N. Baranov, *Ekonomika ispol'zovaniya udobreniy*, Moscow, 1974, p. 59.

[20] G. P. Rudenko and V. V. Miloserdov, *Teoriya i praktika planirovaniya sel'skogo khozyaystva*, Moscow, 1976, p. 160.

Table 4
Average Fertilizer Response Rates, Countrywide

| | Fertilizer Applications (Million Metric Tons) | Response Rates (Tons of Grain per Ton of Fertilizer) |
|---|---|---|
| Before 1969 | 1 to 10 | 2 to 3 |
| 1969-1973 | up to 20 | 1.2 to 1.5 |
| 1974-1975 | up to 25 | 1.2 to 1.3 |

average rate of 0.61 centners per hectare. Grain crops benefited mainly from more precipitation; weather accounted for about 0.31 centners of the average increase in yields per hectare.[21] Fertilizer applications during the period rose by an average of 0.11 centners per hectare per year. If average response for this period is assumed to fall into the 1.2 to 1.5 range, grain yields rose an average of 0.13 to 0.16 centners per hectare because of increased use of fertilizer. An estimated 0.04 centners per hectare came from reducing spring wheat area while expanding areas sown to higher yielding barley and winter wheat. [22] The remaining average increase in yields, 0.10 to 0.13 centners per hectare, was the result of other changes, such as improved varieties of grain and the like. The following tabulation summarizes the various sources of additional yield between 1962 and 1974.

| | Percent |
|---|---|
| Total yield increase | 100 |
| Increase from: | |
| Rising precipitation | 51 |
| Increased use of fertilizer | 21 to 26 |
| Restructured sown area | 7 |
| Other | 16 to 21 |

## Outlook for 1976-80

According to the draft directives for the Tenth Five-Year Plan (1976-80), the high priority enjoyed by the fertilizer program will be continued during the next five years.

- Total fertilizer production is to increase by three-fifths. Production of phosphate fertilizers is scheduled to grow faster than nitrogen and potash fertilizers in order to improve product structure. Reportedly, phosphorus will account for 35 percent of all fertilizers in 1980, compared with 29 percent in 1975.
- The share of technologically advanced fertilizers, including multinutrient, highly concentrated, and granulated fertilizers, will increase to 88 percent of the total, compared with 70 percent during 1971-75.
- Nutrient content is to increase to 40.6 percent from 35 percent in 1975.
- Applications to grain will double.

Achievement of these ambitious targets depends on the construction of dozens of large, modern production facilities. New production capacity needed to meet the 1980 goals probably will not be operating before 1977-78; therefore, fertilizer supplies probably will grow slowly until 1978 and more rapidly thereafter as new plants start producing.

Soviet planners are counting on increased applications of fertilizer to account for 55 percent of the boost in grain output during 1976-80.[23] Yearly grain production during this period is planned at 220.4 million tons.[24] If achieved, this would represent a 21.4-percent improvement, or a cumulative increase of 194 million tons over the

[21] CIA, *op. cit.*, p. 14.

[22] The estimated increase in grain yields from restructuring sown area was derived as follows: Average 1959-61 yields for spring wheat, winter wheat, and barley were multiplied by area sown to these crops in 1960 and 1974. The resulting output figures were added and then divided by sown area to derive weighted average yield for the three grains in 1960 and 1974.

[23] *Ekonomika sel'skogo khozyaystva*, No. 4, 1976, p. 49. In addition, there is to be some restructuring and expansion of the grain area. Higher yield grains such as winter wheat, winter rye, spring barley, and corn are to be emphasized. The area under pulses is also to expand. Land reclamation and the use of fertilizer on pastures and on fodder crops is to increase yields of these grain crops to the extent that pasture land can be switched to grain. Double cropping on irrigated land and the expanded use of irrigated land for grain are also to boost production. In addition, more liming will support the program. Moreover, the availability of higher quality machinery is to improve the speed of sowing and harvesting, allowing the harvest of another 6 million tons of grain yearly. (*Zernovoye khozyaystvo*, No. 3, 1976, p. 2-3, 18-19.)

[24] The figure for the boost in grain output from increased fertilizer application (55 percent) referred to the original 1976-80 goal of 215 million to 220 million tons.

preceding five years. An increase of this scope is not unprecedented; production during the last half of the 1960s exceeded the first half by 29 percent, as shown in table 5.

Table 5
Growth of Grain Output

| | Annual Average Production (Million Metric Tons) | Change over Preceeding Five-Year Period (Percent) |
|---|---|---|
| 1956-60 ..... | 121.5 | 37.3 |
| 1961-65 ..... | 130.3 | 7.2 |
| 1966-70 ..... | 167.6 | 28.6 |
| 1971-75 ..... | 181.6 | 8.4 |
| 1976-80 Plan | 220.4 | 21.4 |

To achieve the planned gain for 1976-80, grain crops are scheduled to receive a minimum of 50 million tons (standard units) of mineral fertilizer annually by 1980, and application rates will be about four centners per hectare—twice the 1975 rate. These data imply a marginal response rate of 1.1.[25] The corresponding average response rate is 1.2, which is consistent with the pattern of diminishing returns illustrated in table 4.

Fertilizer allocations are planned to rise most sharply in grain areas with sufficient moisture for high response rates. Included in this area are the RSFSR nonchernozem zone, Krasnodar, the southwest portions of the Ukraine, Belorussia, and the Baltic republics. By 1980, grain crops in this area will receive 7 to 9 centners of fertilizer per hectare—up from 4.5 centners in 1974. The RSFSR nonchernozem zone is to provide 31 million tons of grain in 1980, compared to an annual average output of 20 million tons during 1971-75.

Supplies of fertilizer for the 1976-80 five-year plan may be inadequate, however. Even if production goals for 1980 are met, planned applications to grain cannot be made unless transportation and storage losses are reduced. If losses remain at their present level of 10 to 15 percent of deliveries to agriculture, crops will receive about 100 million tons of fertilizer in 1980 instead of the 115 million tons needed to make planned applications on all crops.

Prospects for reducing losses are dim because investment in transportation and storage is not keeping pace with the rapidly growing fertilizer supply. For example, the 1971-75 plan stipulated a capacity of 20 million tons for bulk transportation of fertilizer in specialized, self-unloading railroad cars by the end of 1975—about one-fourth of 1975 deliveries to agriculture. Development of specialized machinery to support bulk transport is also behind schedule.

To double applications to grain by 1980 if losses remain at 10 percent, the Soviets would have to divert fertilizer from other uses. Higher fertilizer applications to grain, however, will not likely be made at the expense of technical crops. Furthermore, with the increasing priority of livestock, allocations of fertilizer to nongrain feed crops are also important. On balance, plan fulfillment over the next five years for applying fertilizer to grain is likely to remain about 80 percent. Even at this rate, fertilizer promises to be the major weapon in the Soviet arsenal to increase grain production.

The impact of increased fertilizer use over the next five years will depend not only on the Soviets' success in fulfilling application plans and on response rates but also on a number of factors, particularly weather, which is the dominant

[25] This calculation was made as follows:

1. Annual average grain production 1971-75 - 181.6 million tons
2. Annual average grain production originally planned for 1976-80 - 217.5 million tons
3. Planned annual average increase in grain production (line 2 minus line 1) - 35.9 million tons
4. Planned increment due to fertilizer (55 percent) - 19.7 million tons
5. Planned increment in fertilizer application - 17.7 million tons
6. Response rate (line 4 divided by line 5) - 1.1.

We do not know how Soviet planners separate the effects of fertilizer and nonfertilizer technology in making this calculation. In practice the effects of fertilizer alone are difficult to measure in estimating response rates. The alternative assumption—that all increases in output should be attributed to fertilizer—produces an overall response rate of 2 for 1976-80. This is derived by dividing planned increases in grain output (35.9 million tons) by the planned increment in fertilizer applications (17.7 million tons), which is clearly an overstatement of the return to fertilizer. Output gains attributable to improved cultural practices, use of other agricultural chemicals, liming, improved varieties of grain, and the like help boost yields.

variable in determining crop size. We do not know what assumptions Soviet planners made about weather in determining their original goal for 1976-80 of 215 million to 220 million tons of grain annually. As a test of the reasonableness of the plans, we have prepared two projections of grain output for 1976-80. Both projections assume that the nearly normal weather of the early 1960s will prevail during the period and that the marginal response of fertilizer will be 1.1.[26] Although these assumptions are too gross to permit year-to-year predictions of grain production, we believe they are precise enough to indicate the trend in production and the potential importance of technology, especially fertilizer.

Our projections incorporate the 1975 benchmark for grain output used in our recent study on the impact of climate change on grain production.[27] Under Projection I, which assumes fertilizer goals are met, average annual production during 1976-80 would equal 212 million tons, and average yields would be 16.5 centners per hectare.[28] Projection II, which we believe contains a more realistic assumption about fertilizer applications, results in an average crop of about 200 million tons and average yields of 15.6 centners per hectare. The tabulation compares (a) Soviet plan goals, (b) Projections I and II, and (c) the projection used in the climate study.[29] Actual grain production may be considerably higher or lower than projected, depending primarily on weather conditions. Grain output in 1976 was 223.5 million tons, and a crop of 194 million tons is estimated for 1977.

| | Yield (Centners per Hectare) | Annual Average Output (Million Metric Tons) |
|---|---|---|
| Soviet plan goal | 17.2 | 220.4 |
| Projection I ..... | 16.5 | 212 |
| Projection II .... | 15.6 | 200 |
| Climate study.... | 15.4 | 197 |

## Projections I and II

The two projections differ in the assumptions about the amount of fertilizer applied to grain

[26] In examining the impact of fertilizer on grain yields, we tested a second methodology, which we discarded because it did not produce reasonable projections. The methodology was derived from a United Nations study of crop yields and fertilizer applications in 40 Western countries. (Food and Agriculture Organization, *Crop Production Levels and Fertilizer Use*, Rome, 1962). Cross-sectional data on grain yields per hectare and fertilizer applications to all arable land were used for 1950-58. Data were not available for fertilizer applications to grain alone. Moreover, the UN study did not separate the contribution of fertilizer from the contribution of other factors in increasing grain yields. The increases in yields were taken as an expression of technological advances in agriculture, and the average consumption per hectare of fertilizer was assumed to represent the total input effort made. The projection was high to the degree that weather has improved or advances have taken place in harvesting practices, seed variety, and the like.

Although these assumptions appear reasonable, the formula yielded an estimate of grain output for 1980 that is clearly too high: 22 centners per hectare and a total of 280 million tons. With average annual output for 1976-80 planned at 220.4 million tons and yields at 17 centners per hectare, grain output envisioned by this technique seems completely out of reach.

Assuming fertilizer plans are met and recent weather holds, the UN formula predicts a total annual increment of 38.7 million tons of grain during 1976-80. Reducing fertilizer applications would lower the additional grain by a like amount.

[27] CIA, *op. cit.* Our study of the impact of climate changes grouped the years since 1962 according to weather conditions. Weather in 1962-65 was near the long-term norm, whereas 1970-73 was characterized by favorable, or above average, weather. Each period was used to derive a 1975 benchmark from which to extrapolate grain output to 1980. In projecting to 1980, however, the climate study used the long-term technology trend (including fertilizer), which does not account for Soviet plans to accelerate the growth of grain-growing technology during 1976-80.

[28] Estimates of crop size from Projections I and II depend on the choice of the 1975 benchmark. Possibilities include the planned output of 205 million tons, actual output of 141 million tons, and a value of a 195 million tons derived from the long-term trend. For this report—as in our climate study—we chose a fourth procedure: a base of 184 million tons, which was derived by projecting the trend in Soviet grain production during 1962-65, the period of near normal weather. Although the base of 184 is consistent with the planned response rate of 1.1 and with Soviet grain output goals for 1976-80, it is below the long-term trend and may also be below the base used by Soviet planners to reconcile goals for fertilizer applications and grain output. There is some support for an alternative set of assumptions. Use of the long-term trend for the base, given grain output goals, implies a lower response rate. Plotting annual fertilizer applications to all crops against grain output during 1960-76 suggests that the total response associated with fertilizer may be somewhat less than 1.1. Regardless of the base used for *ex ante* statistical projections, a return to "normal" weather over the next several years would be reflected *ex post* in lower response rates to fertilizer and other technology.

[29] The climate study multiplied the projected yield times 130 million hectares to obtain estimated output of 200 million tons. This report uses recently published Soviet plan data on grain area of 128 million hectares in 1980. Adjusting the climate study area to 128 million hectares yields an estimate of 197 million tons.

Table 6

Annual Increases in Grain Production

Million Metric Tons

| | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|
| Projection I | | | | | |
| Total [1] | 8.0 | 7.6 | 10.2 | 12.5 | 12.7 |
| Additional grain from fertilizer [2] | 4.4 | 4.2 | 5.6 | 6.9 | 7.0 |
| Additional grain from other sources [3] | 3.6 | 3.4 | 4.6 | 5.6 | 5.7 |
| Projection II | | | | | |
| Total | 2.3 | 5.6 | 6.8 | 7.8 | 7.9 |
| Additional grain from fertilizer [2] | 0 | 3.3 | 4.5 | 5.5 | 5.6 |
| Additional grain from other sources [4] | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |

[1] Derived by dividing additional grain from fertilizer by 0.55 in accordance with Soviet plans that call for increased use of fertilizer to account for 55 percent of increased output.

[2] Table 7.

[3] Total increase minus the increase from fertilizer.

[4] Assumes increments from other sources will be half the planned level during 1976-80.

and the impact of technology other than fertilizer. Projection I assumes that goals for increased fertilizer application and implementation of nonfertilizer technology are met (see table 6). Projection II assumes that only four-fifths of the fertilizer plan for grain will be met—the record of the recent past—and only half of the planned increases in nonfertilizer technology are realized.[30] Thus, under Projection I, fertilizer applications to grain will increase from 2.0 centners per hectare in 1975 to 4.0 centners in 1980 (see table 7). Plans probably will not be met because of losses in transportation and storage. Under Projection II, therefore, application rates would be only 3.2 centners per hectare in 1980.

The basis of the implicit Soviet plan for nonfertilizer technology to contribute a cumulative total of 87 million tons to grain production over the current five-year period is uncertain, although increased use of irrigated and drained land evidently will play a large role.[31] The effects of fertilizer and nonfertilizer technology, however, are inseparably linked in the case of land reclamation; therefore, Soviet plans for increasing grain output through land reclamation were not quantifiable under the assumptions of Projections I and II, which require separation of the contributions of fertilizer and nonfertilizer technology. Another source of increased grain output is restructuring the sown area to favor higher yielding grains such as winter wheat, winter rye, spring barley, and corn. By 1980, spring barley and oats will occupy an additional 8 million to 8.5 million hectares, and corn area will increase by 2 million to 2.5 million hectares. Soviet planners expect an increase of 3 million to 3.5 million tons of barley and oats as well as a doubling of corn output.[32] Like land reclamation, however, these output increases will be the result of both fertilizer and nonfertilizer technology.

[30] Although this assumption is arbitrary, generally the Soviets have underfulfilled their plans for gains in yields from improved cropping practices, introduction of higher yielding varieties, use of pesticides and herbicides, expansion of sowings on irrigated land, and other components of "technology gains." There is no way to quantify the effect of these shortcomings on grain production.

[31] Grain output on irrigated and drained land is scheduled to grow from 11.3 million tons in 1975 to 38 million tons in 1980. If plans are met, a cumulative total of 68 million tons of additional grain could be derived from these sources. Because fertilizer application plans for reclaimed land have not been published, the 68 million tons could not be allocated between fertilizer and nonfertilizer technology.

[32] *Zernovoye khozyaystvo*, No. 3, 1976, pp. 2-3.

Table 7

Fertilizer Applications to Grain

| | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|
| **Projection I** | | Centners Per Hectare | | | |
| Mineral fertilizer applied [1] | 2.3 | 2.6 | 3.0 | 3.5 | 4.0 |
| | | Million Metric Tons | | | |
| Total fertilizer applications [2] | 29 | 33 | 38 | 44 | 51 |
| Increments in fertilizer applications [3] | 4.0 | 3.8 | 5.1 | 6.3 | 6.4 |
| Additional grain attributable to fertilizer [4] | 4.4 | 4.2 | 5.6 | 6.9 | 7.0 |
| **Projection II** | | Centners Per Hectare | | | |
| Mineral fertilizer applied [1] | 2.0 | 2.1 | 2.4 | 2.8 | 3.2 |
| | | Million Metric Tons | | | |
| Total fertilizer applications [2] | 25 | 26 | 31 | 36 | 41 |
| Increments in fertilizer applications [3] | 0 [5] | 3.0 | 4.1 | 5.0 | 5.1 |
| Additional grain attributable to fertilizer [4] | 0 | 3.3 | 4.5 | 5.5 | 5.6 |

[1] Data for 1976-79 are interpolated using 1975 and 1980 data and average annual rates of growth.

[2] Application rates times hectares sown to grain in the socialized sector.

[3] Calculated from unrounded data.

[4] Increments in applications times response rate of 1.1. Unless the response rate function shifts upward substantially, the response rate will be somewhat higher than 1.1 in 1976 and lower than 1.1 in 1980 consistent with the principle of diminishing returns. Soviet data, however, provide only an average response rate for the entire period.

[5] Assumes that the 1976 application rate was the same as 1975. Eighty percent of the 1976 plan would put the 1976 application rate at 1.8—below the 1975 rate of 2.0. Since a decline in the application rate was unlikely, we assume no change for Projection II; thus, under the assumptions of Projection II, increases in 1976 grain yields came from sources other than mineral fertilizer.

The reasonableness of the goal for 1976-80 for increases in yields from sources other than fertilizer cannot be gauged; but based on the past, prospects for achievement seem dim. For example, a Soviet agronomist implied that periods for growing grain in 1971-75 were to be shortened chiefly by removing present delays in sowing, cultivation, and harvesting, contending that delayed harvesting alone causes losses of 10 million to 13 million tons of grain per year.[33] There is no evidence, however, that significant improvement occurred in this area. Western observers generally agree that no substantive success in developing and disseminating new seed varieties has been evident recently, that the use of chemicals for weed and pest control is behind schedule, and that expansion of fallow and anti-erosion cropping fell below planned levels. The average area under clean fallow during 1971-75 declined from 18.4 million hectares in 1970 to 11.2 million hectares in 1975.[34]

[33] F. Savitskiy, *Ekonomika sel'skogo khozyaystva*, No. 4, 1972, p. 10.

## International Comparisons of Fertilizer Use

Data on world fertilizer consumption provide a crude benchmark for gauging the Soviet record. It is impossible, however, to compare the Soviet fertilizer program with that of other countries despite substantial international data on aggregate fertilizer production, trade, and consumption.[35] Lack of aggregate country data on fertilizer use by crop limits meaningful international comparisons. The US Department of Agriculture reports that "available data on food-crop response to fertilizer are inconclusive and inconsistent, particularly in the aggregate."[36] The validity of international comparisons of fertilizer use is further limited because of varying soil

[34] Under the practice of clean fallowing, the land is not planted and is cultivated only as needed to prevent weeds from growing. The practice also permits accumulation of moisture and nitrogen in the soil.

[35] See, for example, Food and Agriculture Organization, *Annual Fertilizer Review 1974*, Rome, 1975.

[36] USDA, Economic Research Service, *Supplement to: World Agricultural Situation, The World Fertilizer Situation: 1975 and 1980*, p. 39

types, moisture conditions, cropping practices, and differences in relative factor costs and product prices. For example, the primary US grain crop is corn, which has high fertilizer requirements, especially for nitrogen. The USSR and Canada produce relatively little corn. As we have seen above, the relative price of fertilizers and wheat in the US and USSR would argue for a relatively greater use of fertilizer per hectare in the USSR—other things held equal.

Between 1960 and 1974, world consumption of fertilizer almost tripled.[37] Growth in use in the Soviet Union has been more than twice the world rate since 1960, but Soviet consumption still lags behind most developed nations.[38] According to a United Nations study, Soviet use in 1960 of nitrogen fertilizer per hectare of arable land was about one-third that in developed nations (see table 8). By 1974, the ratio had risen to 90 percent. The complexity of international comparisons is illustrated by the fact that total consumption in Canada was roughly one-tenth that in the USSR. When measured by dosage per hectare of agricultural land, however, fertilizer usage in Canada was roughly half the USSR (see table 9).[39]

Soviet fertilizer application patterns for grain are similar to those in the US, where applications to wheat increased by over half between 1965 and 1975. As in the USSR, fertilizer use is concentrated in moist areas.[40] For example, in 1975, 92 percent of wheat fields in the Great Lakes area received an average of 139 kilograms

[37] National Fertilizer Development Center, Tennessee Valley Authority, *Fertilizer Trends 1973*, p. 7.

[38] Data on Soviet fertilizer production, trade, and consumption are provided in Appendix A.

[39] The UN use of "arable" land for some international comparisons and the more inclusive measure "agricultural" land for others adds to the analytical problem.

[40] This and subsequent comparisons of fertilizer use are for wheat only. Ideally, comparisons should include all small grains; but US fertilizer statistics are available only for wheat, corn, and soybeans. Soviet fertilizer application rates for all grain, excluding corn, are assumed the same as the rates for wheat.

Table 8

World Fertilizer Consumption (by Region) [1]

Kilograms [2]

| | 1960 | | | 1965 | | | 1970 | | | 1974 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| **World** | **7.8** | **7.4** | **6.2** | **13.3** | **10.5** | **8.7** | **21.6** | **13.5** | **11.3** | **25.8** | **15.1** | **13.2** |
| **Developed countries** | **18.2** | **20.2** | **16.3** | **28.4** | **27.3** | **20.9** | **39.2** | **31.0** | **24.8** | **41.3** | **28.7** | **24.7** |
| North America [3] | 12.5 | 11.7 | 9.1 | 22.8 | 17.4 | 13.8 | 32.7 | 20.0 | 17.2 | 33.2 | 18.2 | 16.9 |
| United States | NA | NA | NA | 27.0 | 19.7 | 16.3 | 38.4 | 22.7 | 20.0 | 37.7 | 19.7 | 19.4 |
| Western Europe | 30.8 | 34.2 | 32.3 | 46.5 | 43.8 | 39.3 | 67.3 | 56.6 | 49.5 | 78.3 | 54.5 | 50.1 |
| Oceania | 1.0 | 26.0 | 3.1 | 2.0 | 34.1 | 4.5 | 3.4 | 24.0 | 4.4 | 4.3 | 20.8 | 4.8 |
| Other | 44.1 | 34.9 | 34.2 | 47.0 | 38.7 | 35.8 | 53.3 | 46.3 | 35.3 | 47.6 | 51.4 | 42.6 |
| **Developing countries** | **2.5** | **1.0** | **0.7** | **3.9** | **1.7** | **1.0** | **7.9** | **3.4** | **2.0** | **10.6** | **5.1** | **3.0** |
| Africa | 0.5 | 0.6 | 0.4 | 0.8 | 0.6 | 0.5 | 1.5 | 1.2 | 0.7 | 2.2 | 1.6 | 1.1 |
| Latin America | 4.2 | 2.6 | 2.1 | 6.0 | 3.8 | 2.4 | 10.2 | 6.8 | 4.8 | 13.8 | 10.9 | 6.9 |
| Middle East | 3.6 | 1.1 | 0.1 | 5.8 | 2.1 | 0.2 | 9.8 | 3.9 | 0.3 | 14.5 | 6.4 | 0.6 |
| Far East | 2.9 | 0.7 | 0.4 | 4.4 | 1.4 | 0.9 | 10.8 | 3.1 | 1.9 | 13.8 | 4.2 | 3.2 |
| Other | 1.3 | 0.1 | NA | 4.4 | 0.9 | 0.2 | 4.8 | 1.1 | 0.6 | 10.1 | 2.4 | 3.1 |
| **Centrally planned countries** | **5.6** | **4.6** | **4.7** | **13.7** | **8.5** | **9.1** | **26.5** | **12.7** | **13.3** | **35.2** | **18.0** | **18.5** |
| Asia | 5.1 | 2.1 | 0.4 | 12.8 | 5.1 | 1.6 | 25.7 | 7.1 | 2.8 | 31.1 | 11.5 | 4.7 |
| European USSR | 5.9 | 5.7 | 6.5 | 14.2 | 10.1 | 12.5 | 26.9 | 15.3 | 18.2 | 37.3 | 21.2 | 25.3 |

[1] Data for the non-Communist countries are for the fertilizer years beginning 1 July of the stated year.

[2] Nutrients per hectare of arable land.

[3] Including the United States.

Source: Food and Agriculture Organization, United Nations, *Annual Fertilizer Review, 1974*, Rome, 1975, p. 47, 505; *Annual Fertilizer Review, 1975*, Rome, 1976, pp. 56-62. Arable land includes land used for rotational crops, permanent crops, rotational meadows for mowing or pastures, market and kitchen gardens, and rotational fallow.

Table 9

World Fertilizer Consumption (by Country), 1974/75 [1]

| | Total Consumption (Million Metric Tons of Nutrients) | Percent of World | Consumption per Hectare of Agricultural Land | |
|---|---|---|---|---|
| | | | Kilograms | Index: World Total=100 |
| World | 81.5 | 100.0 | 17.9 | 100.0 |
| United States | 15.9 | 19.5 | 37.2 | 207.8 |
| USSR | 13.7 | 16.8 | 34.9 | 195.0 |
| Australia | 0.9 | 1.1 | 1.8 | 10.0 |
| Canada | 1.2 | 1.5 | 17.9 | 100.0 |
| Argentina | 0.8 | 1.0 | 0.5 | 2.8 |

[1] Agricultural land includes arable land (see table 8) plus land under permanent meadow and pastures. Statistics for the USSR are for calendar year 1974, whereas data for the other countries are for the fertilizer year beginning 1 July.

Source: Food and Agriculture Organization, United Nations, *Annual Fertilizer Review 1975*, Rome, 1976 p. 63-73, 181.

per hectare, whereas only 55 percent of Nebraska's relatively dry wheat area was fertilized, with dosages averaging only 109 kilograms per hectare.

US-USSR comparisons of fertilizer use and wheat output in roughly comparable soil-climate regions are shown in table 10.[41] Only a small share of the total wheat area can be compared because most of the USSR's wheat growing region is like the prairie provinces of Canada. Furthermore, Soviet fertilizer application data is available by republic and not by soil-climate zone. Comparisons are thus limited to areas where Soviet soil-climate zones and republic boundaries coincide.

Overall, wheat yields and fertilizer use are higher in the US than in the USSR. On a regional basis, however, the picture is mixed. In the wet areas of Lithuania and Michigan, where fertilizer application rates are similar, wheat yields are slightly higher in the USSR. The analogous areas of the Ukraine and western Washington, however, have about the same yields with the Soviet area receiving less fertilizer. The Georgian Republic - Oklahoma comparison shows greater fertilizer use and higher wheat yields in the USSR.

[41] USDA, *Future Crop Yields and Fertilization in the Soviet Union*, 1964. Analogies were selected for comparability in production conditions such as soil, climate, and length of growing season. Comparisons of other crops require different analogies.

Table 10

US and USSR: Fertilizer Use and Wheat Yields, 1975

| | Area Receiving Fertilizer | Nutrients Applied [1] | Annual Average, 1971-75 Wheat Yield [2] |
|---|---|---|---|
| US | 63% | 57 | 20.4 |
| USSR | 48% | 42 | 14.5 |
| Analogous Regions | | | |
| Nebraska | 55% | 56 | 24.0 |
| Washington | 97% | 122 | 28.8 |
| Ukranian SSR | 86% | 70 | 28.4 |
| Minnesota | 95% | 134 | 22.8 |
| Michigan | 98% | 152 | 25.6 |
| Lithuanian SSR | 99% | 140 | 28.8 |
| Oklahoma | 66% | 64 | 16.0 |
| Georgian SSR | 86% | 136 | 17.9 |

[1] Kilograms per hectare.

[2] Centners per hectare.

Sources: USDA, *Fertilizer Use on Crops: 1975*, unpublished manuscript, p. 10; USDA, *Fertilizer Situation*, 1977, p. 17.

*Narodnoye khozyaystvo SSSR, v 1974, godu*, pp. 347, 357. USDA, *Agricultural Statistics*, 1975, p. 6. The Soviet yields shown represent a 10-percent reduction of the officially claimed yields given in the sources. This minimum discount reflects a correction for the excess moisture and trash beyond that found in US wheat.

## APPENDIX A

### Mineral Fertilizer Production, Net Exports, and Deliveries to Agriculture

Million Metric Tons

| | 1960 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1980 Plan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standard Units** [1] | | | | | | | | | | | | | | | | |
| Production [2] | 13.9 | 17.3 | 19.9 | 25.5 | 31.3 | 35.8 | 40.1 | 43.4 | 45.8 | 55.4 | 61.4 | 66.1 | 72.3 | 80.4 | 90.2 | 143 |
| Exports | 1.1 | 1.7 | 1.9 | 1.3 | 1.5 | 2.1 | 2.8 | 3.3 | 3.3 | 5.0 | 5.6 | 5.9 | 6.6 | 7.6 | 7.8 | * |
| Deliveries to agriculture | 11.4 | 13.6 | 15.9 | 22.0 | 27.1 | 30.5 | 33.7 | 36.2 | 38.8 | 45.6 | 50.5 | 54.8 | 60.0 | 65.9 | 75.3 | 115 |
| Nitrogen | 3.7 | 5.2 | 6.6 | 8.6 | 11.1 | 13.0 | 15.1 | 16.8 | 18.5 | 22.5 | 25.3 | 27.4 | 30.5 | 32.9 | 36.1 | * |
| Phosphorus | 5.8 | 6.3 | 7.0 | 9.8 | 11.3 | 12.9 | 13.4 | 14.0 | 14.7 | 16.9 | 18.5 | 19.5 | 20.7 | 24.0 | 27.0 | * |
| Potassium | 1.8 | 2.0 | 2.2 | 3.4 | 4.6 | 4.6 | 5.1 | 5.2 | 5.6 | 6.2 | 6.7 | 7.8 | 8.7 | 8.9 | 12.0 | * |
| **Nutrients** [1] | | | | | | | | | | | | | | | | |
| Production [2] | 3.3 | 4.1 | 4.6 | 6.0 | 7.4 | 8.4 | 9.4 | 10.2 | 10.7 | 13.1 | 14.7 | 15.9 | 17.4 | 19.4 | 22.0 | * |
| Exports | 0.37 | 0.54 | 0.61 | 0.42 | 0.48 | 0.67 | 0.92 | 1.1 | 1.1 | 1.8 | 2.0 | 2.2 | 2.4 | 2.9 | 3.0 | * |
| Deliveries to agriculture | 2.6 | 3.1 | 3.6 | 5.0 | 6.3 | 7.0 | 7.7 | 8.3 | 8.9 | 10.4 | 11.4 | 12.5 | 13.8 | 15.0 | 17.5 | * |
| Nitrogen | 0.8 | 1.1 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.4 | 3.8 | 4.6 | 5.2 | 5.6 | 6.2 | 6.7 | 7.4 | * |
| Phosphorus | 1.1 | 1.2 | 1.3 | 1.8 | 2.1 | 2.4 | 2.5 | 2.6 | 2.8 | 3.2 | 3.5 | 3.7 | 3.9 | 4.5 | 5.1 | * |
| Potassium | 0.8 | 0.8 | 0.9 | 1.4 | 1.9 | 1.9 | 2.1 | 2.2 | 2.3 | 2.6 | 2.8 | 3.2 | 3.6 | 3.7 | 5.0 | * |

[1] All data are from official Soviet statistics on production, exports, and deliveries of fertilizer. Nutrient values are calculated based on the following assumptions of nutrient content: phosphate fertilizers, 18.7-percent $P_2O_5$; ammonium sulfate, 20.5-percent N; potash, 41.6-percent $K_2O$.

[2] Fertilizer production is allocated to exports, agriculture, industrial use, and inventory change; statistical information is not available on inventory change or industrial use.

*Not available.

## APPENDIX B

### Derivation of Applications of Mineral Fertilizer to Crops

This appendix is a description of the sources and methodology used in deriving the estimates presented in tables B-1 and B-2. For the most part, total fertilizer applied is the product of the application rate and hectares sown in the socialized sector of agriculture. In some cases, however, total applications

Table B1

Mineral Fertilizer Application to Crops

Million Metric Tons [1]

| | 1960 | 1965 | 1970 | 1972 | 1975 | 1980 Plan |
|---|---|---|---|---|---|---|
| **Total applications** | **11.29** | * | **35.92** | **45.17** | **73.18** | **115** |
| Grain | 2.19 | 5.97 | 14.62 | 19.07 | 25.20 | 51 |
| Forage crops, grasses, cultivated meadows, and pastures | 1.40 | 2.60 | 7.20 | 10.2 | 20.93 | 35 |
| Technical crops | 5.96 | * | 10.21 | 11.02 | 15.31 | 17 |
| Cotton | 2.48 | 3.20 | 4.65 | 4.76 | 5.46 | * |
| Sugar beets, industrial | 1.89 | 3.22 | 3.56 | 4.15 | 6.20 | * |
| Flax | 0.89 | 0.81 | 0.72 | 0.80 | 3.65 | * |
| Sunflower seeds and other | 0.70 | * | 1.28 | 1.31 | | |
| Potatoes | 1.08 | 1.30 | 2.27 | 2.76 | 8.20 | 10 |
| Vegetables and melons | 0.38 | 0.62 | 0.82 | 1.32 | 1.39 | |
| Orchards and vineyards | 0.28 | * | 0.80 | 0.80 | 2.15 | 2 |

[1] Standard units.

* Not available.

* Planovoye Khozyaystvo #3, 1978 p59

Table B2

Mineral Fertilizer Application Rates to Crops

Standard Units [1]

| | 1960 | 1965 | 1970 | 1972 | 1975 | 1980 Plan |
|---|---|---|---|---|---|---|
| Grain | 0.19 | 0.47 | 1.24 | 1.6 | 2.0 | 4.0 |
| Forage crops, grasses, cultivated meadows, and pastures | * | * | 1.2 | 1.7 | 2.0 | 3.1 |
| Technical crops | 4.5 | * | 7.0 | 7.6 | 10.9 | 12.1 |
| Cotton | 11.3 | 13.1 | 16.9 | 17.4 | 18.8 | * |
| Sugar beets, industrial | 6.2 | 8.3 | 10.6 | 11.9 | 16.9 | * |
| Flax | 5.5 | 5.5 | 5.6 | 6.4 | 4.4 | * |
| Sunflower seeds and other | 1.1 | * | 1.8 | 1.9 | | |
| Potatoes | 2.3 | 3.2 | 6.6 | 8.1 | 10.4 | 10.0 |
| Vegetables and melons | 2.4 | 4.4 | 5.4 | 8.3 | 8.2 | |
| Orchards and vineyards | 1.0 | * | 2.7 | 2.7 | 7.2 | 7.2 |

[1] Centners per hectare sown.

* Not available.

are given; and application rates are derived by dividing total applications by sown area. Data on annual fertilizer applications to individual crops are scarce. For 1960, 1965, 1970, and 1972, however, fairly complete data have been assembled. Data for the intervening years—1961-64, 1966-69, 1971, and 1973-74—contain numerous gaps. Total applications of mineral fertilizer and application rates for industrial crops are derived as follows.

### 1960

**Grain**—Total applications in 1960 are from T. P. Unanyants, *Ekonomicheskaya effektivnost' khimizatsii sel'skogo khozyaystva,* Moscow, 1964, p. 48. Application rates are derived by dividing total applications by sown area. Data on sown area are from the Soviet statistical handbooks.

**Forage crops, grasses, cultivated meadows, and pastures**—Total applications are from the source above. Data on sown area are not available to calculate application rates.

**Cotton**—Methodology and sources are the same as those used for grain.

**Sugarbeets**—Application rate is from V. M. Borisov, ed., *Spravochnaya kniga po khimizatsii sel'skogo khozyaystva,* Moscow, 1969, p. 623. Total applications are derived by multiplying the application rate times sown area.

**Flax**—Application rate is that for flax and hemp combined. Methodology and sources are the same as those used for grain.

**Sunflower seeds, other technical crops, potatoes, vegetables, and melons**—Methodology and sources are the same as those used for grain.

**Orchards and vineyards**—Total quantity of fertilizer applied is from Unanyants, *op. cit.* Hectares sown are not readily available in statistical handbooks; therefore, hectares for 1970 were estimated by dividing total quantity of fertilizer applied in 1970 by 1972 application rates from N. N. Baranov, *Ekonomika ispol'zovaniya udobreniy,* Moscow, 1974, p. 59.

### 1965

**Grain and Cotton**—*Doklady i soobshcheniya* No. 45, Moscow, 1968, p. 14.

**Forage crops, grasses, cultivated meadows, and pastures**—Total applications are from A. M. Yemel'yanov, *Osnovy ekonomiki i upravleniya sel'skokhozyaystvennym proizvodstvom,* Moscow, 1972, p. 189.

**Sugar beets**—Application rates for 1965 are from Borisov, *op. cit.*, which also gives 1960 application rates. Total applications are derived by multiplying application rates times hectares sown.

**Flax**—The application rate is arbitrarily estimated at the 1960 level. Total applications are derived as for sugar beets above.

**Potatoes**—See source for grain and cotton.

**Vegetables and melons**—Application rate in kilograms of nutrients is from *Narodnoye khozyaystvo*, 1965, p. 362. Nutrients are divided by 20 percent to obtain standard units. Total applications are derived by multiplying application rates times hectares sown.

1970

**Grain**—Total fertilizer applications in nutrients are given in Baranov, *op. cit.* p. 120. These are converted to standard units by dividing by 22.4 percent. Total applications in standard units are divided by hectares sown to grain to derive the application rate.

**Forage crops, cultivated meadows, and pastures**—Total applications in standard units are from A. M. Yemel'yanov, *op. cit.* Total applications are divided by hectares sown to derive the application rate.

**Cotton, sugar beets, flax, sunflower seeds, potatoes, vegetables, and melons**—Total fertilizer applied to these crops is from Baranov, *op. cit.* p. 59. Total applications are divided by sown area to derive the application rate.

**Orchards and vineyards**—Total applications and the application rate for 1972 are arbitrarily assumed valid for 1970.

1972

**All crops**—Application rates are from Baranov, *op. cit.* pp. 30, 315. Total applications are derived by multiplying application rates times hectares sown.

1975

**Grain**—*Ekonomika sel'skogo khozyaystva* No. 4, 1976, p. 50 gives total applications which are divided by 1975 sown area to obtain application rates. Sown area for all crops in 1975 is from *SSSR v tsifrakh v 1975 godu*, p. 111.

**Forage crops, grasses, cultivated meadows, and pastures**—Total applications are derived as a residual. Application rates are derived by dividing total applications by sown area which is the sum of the official figure for forage crops (65.6 million hectares) and 42.1 million hectares for meadows and pastures.

**Technical crops, orchards, and vineyards**—*Vestnik statistiki*, No. 5, 1976, pp. 95-96 gives application rates in nutrients for cotton and sugar beets. These are converted to standard units by nutrient contents of 20.9 percent for cotton and 23.6 percent for sugar beets. Total applications are derived by multiplying application rates times sown area. Application rates are derived by dividing total applications by sown area.

**Potatoes**—Methodology is the same as for cotton and sugar beets. Nutrient content of fertilizer used is 24.4 percent.

**Vegetables and melons**—These crops are assumed to receive 74 percent of the quantity of nutrients applied to potatoes as in 1973. Derivation of application rates is the same as for cotton and sugar beets.

### 1980 Plan

Application rates for 1980 are estimated by assuming that 115 million tons of fertilizer will be delivered to agriculture in 1980.

**Grain**—Total applications will be about 50 million tons according to A. I. Stepanov in *Zernovoye khozyaystvo*, No. 3, 1976, p. 19. Sown area is estimated by dividing planned grain yield for 1976-80 of 17.2 centners per hectare *(Ekonomika sel'skogo khozyaystva*, No. 4, 1976, p. 44) into planned grain output of 215 million to 220 million tons (*ibid.*). Application rates are derived by dividing 50 million tons by estimated sown area.

**Forage crops, grasses, cultivated meadows, pastures, and technical crops**—Total fertilizer applications are derived as a residual assuming a total supply of 115 million tons. The application rate is derived by dividing total applications by 1975 hectarage.

**Potatoes, vegetables, and melons**—Application rates are held at 1975 levels reflecting the Soviet claim that by the end of the 1971-75 plan, the annual fertilizer needs of these crops will be fully met or almost fully met. See *Gosudarstvennyy pyatiletnyy plan razvitiya narodnogo khozyaystva SSSR na 1971-75 gody*, Moscow, 1972, p. 190; also Pronin in *Ekonomika sel'skogo khozyaystva*, No. 1, 1971, p. 12. For potatoes, actual 1975 applications are used; for vegetables and melons, 1975 plan data are used.